

Interaction of Paddy Varieties and Compost with Flux of Methane in Tidal Swampland

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ABSTRACT

Paddy variety and organic material have a very important role on the flux of methane (CH₄) in rice cultivation, especially in a swamp land. The purpose of this study was to determine the amount of methane emissions released from rice cultivation in acid sulphate soils with the use of different rice straw varieties and composts. This study used a 2 × 2 factorial in a Completely Randomized Design with six replicates. The first factor was rice varieties and the second factor was rice straw compost. The results showed that the smallest emission rate of CH₄ occurred when using Inpara 3 variety without rice straw compost of 0.030 mg.m⁻². day⁻¹, while the largest occurred when using Inpari 30 variety with 5 Mg rice straw compost ha⁻¹ that was equal to 0.571 mg m⁻² day⁻¹.

Keywords: Flux CH₄, Inpara 3, Inpari 30, rice straw compost

ABSTRAK

Varietas padi dan bahan organik memiliki peranan penting terhadap laju emisi gas metana (CH₄) pada lahan pertanian padi, terutama pada lahan basah. Penelitian ini bertujuan untuk menentukan laju emisi gas metana yang dilepaskan pada lahan sawah dengan tanah sulfat masam yang ditanami varietas padi yang berbeda-beda dan diberi kompos jerami padi. Contoh tanah sulfat masam diambil pada Kebun Percobaan Balai Penelitian Pertanian Lahan Rawa (BALITTRA), Tanjung Harapan, Kecamatan Alalak, Kabupaten Barito Kuala, Kalimantan Selatan. Penelitian ini menggunakan perlakuan faktorial 2 × 2 dalam rancangan acak lengkap dengan enam ulangan. Faktor pertama adalah penggunaan varietas padi dan faktor yang kedua adalah aplikasi kompos jerami padi. Hasil penelitian menunjukkan bahwa terdapat interaksi yang nyata antara varietas padi dan aplikasi kompos jerami padi terhadap laju emisi gas metana pada lahan sawah dengan tanah sulfat masam. Lahan sawah yang ditanami padi varietas Inpara 3 tanpa aplikasi kompos jerami padi menunjukkan laju emisi gas metana yang paling rendah yaitu 0,030 mg m⁻² day⁻¹, sedangkan lahan sawah yang ditanami padi varietas Inpari 30 dengan aplikasi kompos jerami padi 5 Mg ha⁻¹ memiliki laju gas metana paling tinggi, yaitu 0,571 mg m⁻² day⁻¹.

Kata kunci: Inpara 3, Inpari 30, kompos jerami padi, laju emisi CH₄

INTRODUCTION

Greenhouse gas emissions (GHG) emissions such as CH₄, CO₂ and N₂O over the past few decades have had an impact on rising earth temperatures predicted to reach 1-3 °C and potentially altering the climate (Annisa 2014). Climate change is quite detrimental to the agricultural sector that is highly dependent on climate. The agricultural sector is said to be one source of GHG emissions, especially methane. Ahyar *et al.* (2012) said that the amount of GHG emissions from rice

field cultivation is around 71% and 76% of the total gas emitted in CH₄ form. Production rates and CH₄ emissions in paddy fields for each area vary depending on soil type, soil management and plant varieties (Setyanto 2006). Sulfuric acid is one of the contributors of methane emissions to the atmosphere. The natural sulphate field with rice cultivation has a CH₄ flux of ± 0,57 ig CH₄ g⁻¹ hour⁻¹, while the intensive sulphate field has a CH₄ flux of 3.53 ig CH₄ g⁻¹ hour⁻¹ (Annisa 2014).

Acid sulphate soil is one of the soil types found in the swamp environments and is classified into sub-optimal soil because it has an unfavorable condition (inter) with low fertility. Low soil fertility is characterized by high soil acidity and deficiency of nutrients such as N, P, K, Ca, and Mg. In addition,

inundated acid sulfate soils will cause CH₄ production to increase in line with methanogenic bacteria that develop in anaerobic state (Annisa 2014). Therefore, the development of rice crops in this field requires a specific and innovative technology approach that is characterized by the increasing of productivity, economic value, and environmental improvement (Masganti 2013).

The addition of organic material on to acid-induced sulfur soils can increase CH₄ emissions and farmers typically use organic insitu materials in the form of rice straw. This type of organic material is commonly used by farmers, managed conventionally known as “tipping-back-scattering” systems, including one of local cultural wisdom in agricultural systems in swamplands (Arsyad *et al.* 2014). Based on the research of Susilawati *et al.* (2013), the application of compost had emission of 762 kg CH₄ ha⁻¹ season⁻¹.

In addition to organic materials, efforts made to reduce the rate of production and methane emissions from paddy fields are using varieties and proper cultivation techniques because rice plants play an active role as a medium transporting methane from paddy fields to the atmosphere. According to Setyanto (2006) more than 90% methane was emitted through aerenkima tissue and intercellular spaces of rice plants, while less than 10% were from water bubbles. The ability of rice plants to emit methane are varied, depending on the nature of physiology and morphology. In addition, each variety has a different age and root activity that is closely related to the volume of methane emissions. Based on these considerations, it is necessary to conduct research related to the use of varieties in rice cultivation in acid sulphate soils that can reduce methane emissions and the role of adding organic material in the form of straw compost in anaerobic conditions to methane emissions. The purpose of this research was to study the difference of methane flux released from rice cultivation in acid sulphate soil with the use of different paddy varieties and rice straw compost.

MATERIALS AND METHODS

The research was conducted at the Greenhouse Research Institute of Rawa Land (BALITTRA) Banjarbaru. This study used a Completely Randomized Design (RAL) with two factors and six replicates. The first factor was the rice varieties which were V1 = Inpara 3, V2 = Inpari 30. The second factor was rice straw compost which were: J0 = without rice straw compost, J1 = rice straw compost (5 Mg ha⁻¹). The used soil had low of pH,

Table 1. The characteristic of soil and rice straw compost.

Parameters	Soil	rice straw compost
pH	2.63	-
Organic-C (%)	3.46	44.16
Soluble-Fe (ppm)	129.65	-
Total-N (%)	0.13	0.84
C/N ratio	26.62	52.57
Texture	Loamy	-
Sand (%)	4	-
Dust (%)	28	-
Loam (%)	68	-
Bulk Density (g cm ⁻³)	0.63	-

Total-N and organic-C values, while high Fe²⁺ solubility. The soil texture is loamy and has a C/N ratio of 26.62. While rice straw compost has a very high Organic-C and Total- N content, with C/N ratio of 52.57. This data can be seen in Table 1. The acid sulphate soil was taken on an area that has not been cultivated (naturally) from the Balittra Experimental Garden in Tanjung Harapan Village, Alalak Sub-district, Barito Kuala District, South Kalimantan. The soil was kept wet, and is so homogeneous. For each tretment, the soil was put into pot of 9 kg. There after, lime was applied to increase the soil pH of 5.0 as much as 125.55 g lime pot⁻¹ (equivalent 3.5 Mg ha⁻¹). Organic material in the form of rice straw compost was given seven days before planting. The applied amount of rice straw compost way based on the recommendation of organic matter applied in tidal land which was 5 Mg ha⁻¹ (Razie *et al.* 2013). Basic fertilization used KCl: SP-36: Urea with doses of 100: 100: 200 kg ha⁻¹. KCl and SP-36 fertilizers were administered once at planting, while urea was given 2 stages, at planting and 4 weeks after planting.

Rice plants aged 21 days were planted as many as three seeds per pot. Thinning was done three days after planting with one plant left per pot, then flooding 5 cm inundation. Soil were analysed for pH, soluble-Fe, and Eh. While methane flux as taken at the time of maximum vegetative. Plant growth was observed periodically every 2 weeks on plant height and number of tillers. Observation of plant biomass was carried out after the removal of CH₄ flukes. The flux calculation on each treatment uses the following equation (Annisa 2014):

$$E = \frac{dc}{dt} \frac{V_{ch}}{A_{ch}} \frac{W_m}{V_m} \frac{273.2}{273.2 + T}$$

Remarks:

- E = CH₄ flux (mg m⁻² minute⁻¹)
 dc/dt = CH₄ rate per time (l l⁻¹ minute⁻¹)
 V_{ch} = chamber volume (m³)
 A_{ch} = chamber area (m²)
 W_m = molecular weight of CH₄ (16 x 10³ mg)
 V_m = volume of 1 mole of gas at standard temperature and air pressure (22.41 x 10⁻³ m³)
 T = average temperature inside the chamber during gas sampling (°C)

Data analysis

Data were analysed using the Least Significant Difference (LSD) test. The analysis used using computer program Gen Stat and SAS 9.1.3 Portable.

RESULTS AND DISCUSSION

Methane Flux

The result analysis of variance showed that the treatment of paddy varieties with rice straw compost significantly influenced CH₄ flux (Figure 1). The smallest value of CH₄ flux of 0.030 mg m⁻² day⁻¹ occurred in the use of Inpara 3 variety without straw compost. While, the largest CH₄ flux occurred in the treatment of Inpari 30 with the rice straw compost of 5 Mg ha⁻¹ that was equal to 0.571 mg m⁻² day⁻¹. This suggests that the application of organic matter in the form of rice straw compost greatly influenced the discharge of CH₄ flux due to rice straw compost was used as substrate for methanogen bacteria to

produce CH₄ in reductive condition. While the rice varieties are only as a release agent of CH₄ into the atmosphere. This is supported by LSD test which shows that rice cultivation using Inpara 3 variety without rice straw compost was not significantly different with Inpari 30 without rice straw compost. Application of rice straw compost with a dose of 5 Mg ha⁻¹ was likely to increase significantly the CH₄ fluxes. This is in line with Yuan *et al.* (2013) that the provision of organic matter on paddy fields created more reductive soil conditions. Applied organic matter causes the increasing supply of electrons which mostly used by bacterium *Methanomonas* sp. to produce CH₄. The increasing of CH₄ flux in the presence of organic matter is determined by the quality and quantity of organic matter. The better the quality of organic materials used, the smaller the resulting CH₄ flux. The results of Annisa (2014) showed that the application of fresh organic matter produced 41.05 µg CH₄ g⁻¹ day⁻¹. It is much greater than the application of compostable organic material that produces flux 4.32 µg CH₄ g⁻¹ day⁻¹.

The CH₄ values were different with different rice varieties. This is related to differences in morphology and physiology as well as the ability to oxidize the roots of CH₄. According to Dubey (2005) the difference in the aerenkhima cavity between rice varieties determines the level of CH₄ emissions. It is shown in this study that Inpara 3 variety release CH₄ flux of 0.119 mg m⁻² day⁻¹ and that is smaller than the CH₄ flux released from Inpari 30 variety of 0.283 mg m⁻² day⁻¹. Based on these results it is assumed that Inpara 3 variety has better root oxidizing capacity than Inpari 30 variety, so the

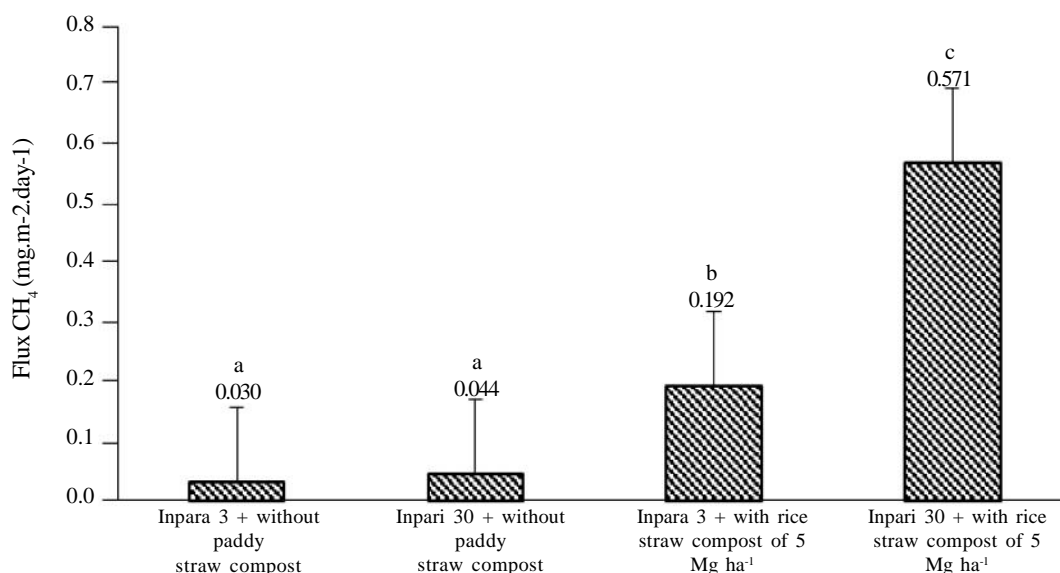


Figure 1. Effect of paddy varieties and rice straw compost on CH₄ flux.

oxygen concentration around the roots increases and methane is oxidized biologically by methanotropic bacteria. The low ability of Inpari 30 variety in oxidizing roots is related to Inpari variety which are rice varieties of Inhibrida irrigation rice. In this condition, the inpari 30 variety are inundated continuously which resulted in restricted growth. In contrast, Inpara 3 variety has an optimal growth if experienced in continuous flooding. In addition to Inpari 30's incomplete inundation with continuous flooding it is suspected that the genetic properties of this variety can release higher CH_4 emissions than Inpara 3.

Soil Chemistry

Redoks Potensial (Eh)

Rice straw compost significantly influenced the redox (Eh) potential of the soil. Changes in the value of Eh occurred due to differences in the supply of oxygen and the presence of organic matter when the soil was inundated. The results showed that rice straw compost can reduce the value of Eh. It can be seen in Figure 2 that the addition of rice straw compost with a dose of 5 Mg ha^{-1} decreased the value of Eh to reach -82 mV. The small value of Eh of this soil causes increasing the released of CH_4 flux. This relationship can be seen in Figure 3. It appears that the value of Eh is negatively correlated to the formation of CH_4 flux shown by the value of $r = -0.602$ which means that the more reductive a soil the further increases the released of CH_4 flux. This is in line with Annisa (2014) who stated that the rate of CH_4 formation with the addition of compost was greater than without compost.

Increasing released of CH_4 is related to the role of organic matter as a substrate in microbial metabolism processes that affect CH_4 emissions because microbial respiration in the soil is related to the reduction-oxidation process that affects the redox potential value (Eh) and becomes an indicator of biogeochemical processes in the soil. The small value of Eh (reductive) causes the release of the CH_4 flux to become larger in relation to the intensification of the decomposition process under stagnant conditions. According to Cyio (2008) organic matter will cause the concentration of H^+ in the soil decreases, so it can push the decrease of the number of electrons in the soil solution. While the number of electrons in the ground is directly proportional to the redox potential which means the decrease in the number of electrons will cause a decrease in the value of Eh.

pH

Paddy varieties and rice straw composts did not significantly affect the soil pH value (Table 2). The application of lime and additional rice straw compost has not been able to significantly increase the pH of the soil. This is due to the buffer power of the soil to the outside factor is given. The ability of ground buffer power is strongly influenced by soil texture. Clay-dominated texture increases the buffer power of the soil. This is supported by the results of Mariana (2013) who study that the buffer capacity of the soil will be greater if the soil is more fine. The texture of the soil is dominated by 68% clay of fraction (Table 1). Clay fraction is soil buffer factor, so the application of lime and rice straw compost can only increase the soil pH from 2.83 to 3.82. This low pH causes the Fe^{2+} concentration in the soil increasing.

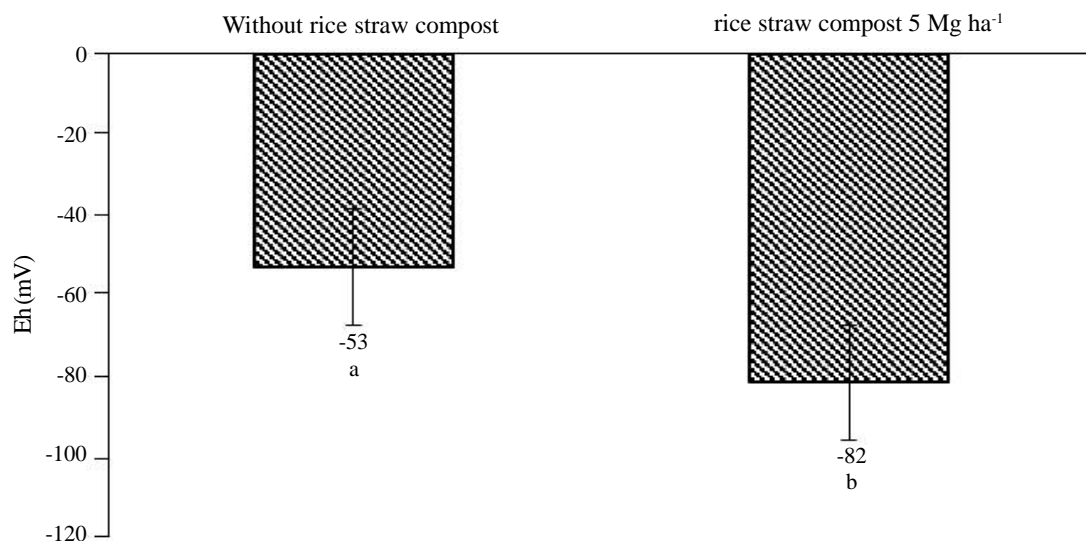


Figure 2. Effect of rice straw compost on soil Eh.

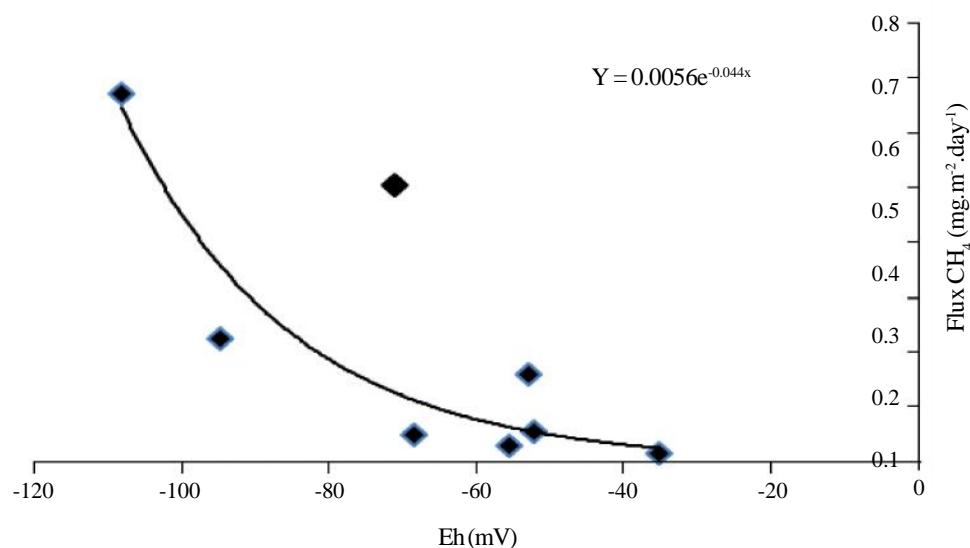


Figure 3. Relation Eh with CH_4 flux on acid sulphate soils treated varieties and paddy straw compost.

While there are a positive correlation between pH and Fe^{2+} concentration. The range of values is from 3.22 to 3.82. The presence of OH^- ions is what causes the increase in pH value. The increase of Fe^{2+} occurs until the pH value reaches 5. This is supported by the opinion of Breemen and Buurman (2003) which states that iron Fe^{2+} increases to soil pH 5 and decreases with increasing soil pH value.

Ferro Iron

Application of rice straw compost increased the Fe^{2+} solubility in soil. Iron in the form of Ferri (Fe^{3+}) to be reduced to iron ferro (Fe^{2+}). This is supported by the opinion of Fahmi *et al.* (2009) who stated that applying organic matter is a source of energy for iron-reducing microorganism which causes

higher Fe^{2+} concentration in soil. Husna (2014) also stated the increasing of ferro value in the soil caused by the application of organic matter. The compost of rice straw provided used in this study has a C/N ratio of 52.57 which means that its organic-C content can be a source of energy for iron-reducing microorganisms. In addition, the increasing of Fe^{2+} due to rice straw compost might be due to the source of organic matter which had high amounts of Fe. According to Annisa (2014), Fe content on rice straw compost is as much as 0.707%.

Plant Growth

Plant height

The results of variance analysis shows that the varieties had significant effect on the plant ages 2

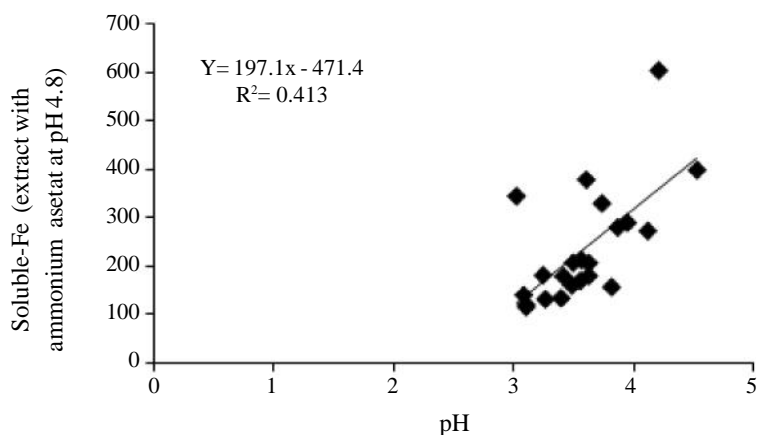


Figure 4. Relationships between pH and soluble-Fe in acid sulphate soils treated by paddy varieties and rice straw compost.

Table 2. Effect of paddy varieties and rice straw compost on soil pH.

Treatment	Soil pH
Inpara 3 + without rice straw compost	3.26 ^a
Inpara 3 + rice straw compost of 5 Mg ha ⁻¹	3.67 ^a
Inpari 30 + without rice straw compost	3.58 ^a
Inpari 30 + rice straw compost of 5 Mg ha ⁻¹	3.68 ^a

and 10 of weeks after planting (WAP) and very significant at the plant age of 4, 6, and 8 WAP. The difference in plant height at 2nd and 10th weeks is likely due to the beginning of growth occurred at 2nd week and at 10th week the growth of paddy is in primordial time, so the plant height significantly difference. This is clarified by Makarim and Suhartatik (2009) who stated that after experiencing the vegetative period, paddy plants will have the primordia period. While the differences in grow were due to differences in varieties because of the different in the plant genetic nature. These genetic differences result in Inpara 3 and Inpari 30 varieties having different traits and characteristics.

Number of Tillers

Varieties treatment had a very significant effect on the number of tillers of rice aged 8 and 10 WAP. Figure 7 shows that Inpara 3 varieties have higher number of rice tillers compared to Inpari 30 varieties. The difference of the number of tillers between Inpara 3 and Inpari 30 varieties was likely due to the difference in photosynthetic ability between the varieties. Inpara 3 is more active in photosynthesis so has more number of tillers. According Yuwono *et al.* (2012) the more active photosynthesis will be the

more asimilat produced. This assimilate is indispensable for cell division, especially vegetative division which resulted in the formation of new saplings.

Plant Biomass

It was shown that Inpara 3 rice varieties had higher biomass values than Inpari 30 varieties. Varieties used significantly affected rice biomass. Inpara 3 varieties have larger biomass compared to Inpari 30 varieties. This might be due to several factors such as the difference of photosynthetic capability and plant adaptability to the environment, especially on continuous flooding. Inpara 3 varieties tend to be more adaptive to continuous flooding as resulting in greater biomass. Besides, it is known that plant height and number of Inpara 3 tillers is bigger than Inpari 30 so as to produce larger biomass. This is supported by Rudyanto *et al.* (2014) that increased plant height and number of tillers will affect the formation of plant biomass.

CONCLUSIONS

Inpara 3 varieties without the largest rice straw compost reduced methane. Inpara 3 without

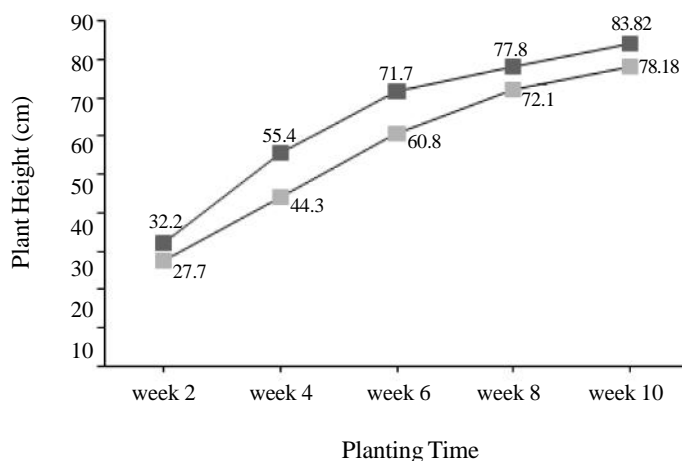


Figure 5. Plant height during the growth of paddy of different varieties. —■—: Inpara 3 and -■-: inpari 30.

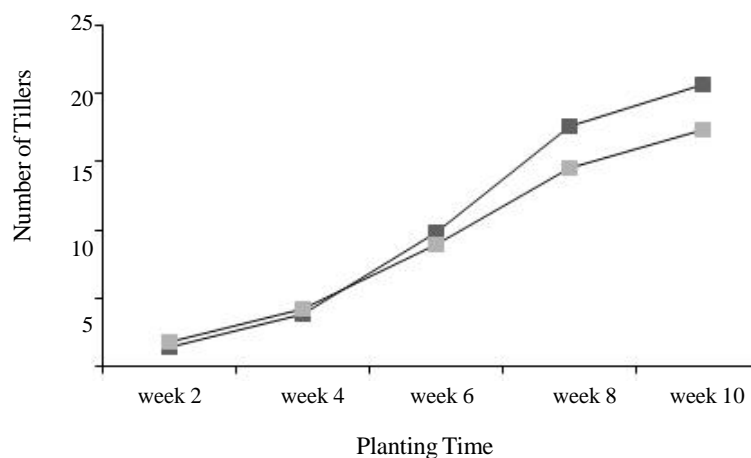


Figure 6. Number of Tillers of different varieties during the growth of paddy. —■—: Inpara 3 and —□—: Inpari 30.

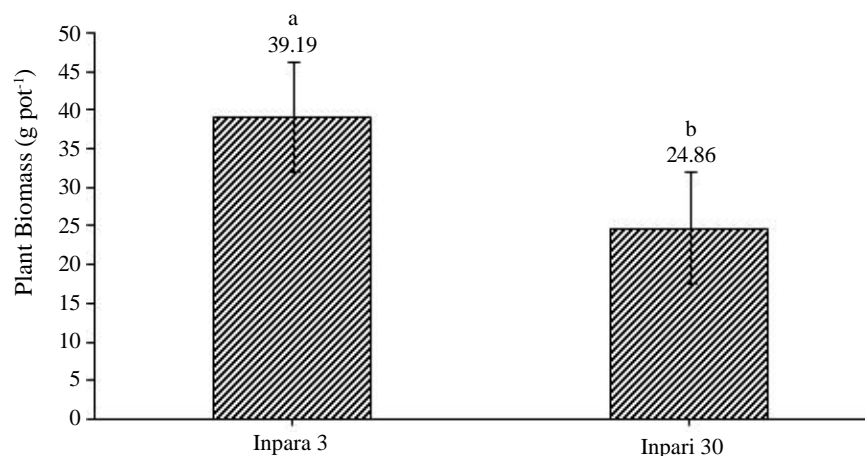


Figure 7. Effect of paddy varieties on plant biomass.

compost application released methane emissions of $0.30 \text{ mg.m}^{-2}.\text{day}^{-1}$. The ability of varieties to reduce methane emissions depend on morphology, physiology and crop adaptability. So, the use of different varieties can provide different methane emission values. In addition, the application of rice straw compost in anaerobic condition can increase the value of the soil CH_4 flux will become more reductive in line with increasing bacteria *Methanomonas* sp. that can produce CH_4 .

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